DEPARTMENT OF ENERGY	LESSON PLAN
	Course: Radiological Control Technician
	Unit: Fundamental Academics
	Lesson: 1.02 Unit Analysis & Conversion

Learning Objectives:

1.02.01　Identify the commonly used unit systems of measurement and the base units for mass, length, and time in each system.

1.02.02　Identify the values and abbreviations for SI prefixes.

1.02.03　Given a measurement and the appropriate conversion factor(s) or conversion factor table, convert the measurement to the specified units.

1.02.04　Using the formula provided, convert a given temperature measurement to specified units.

References:

1. "Health Physics and Radiological Health Handbook"; Scinta, Inc; 1989.
2. **DOE-HDBK-1010-92** (June 1992) "Classical Physics" DOE Fundamental Handbook; US Department of Energy
3. "Nuclides and Isotopes"; Fourteenth Edition, General Electric Company; 1989
4. "Chemistry: An Investigative Approach"; Houghton Mifflin Co., Boston; 1976
5. "Introduction to Chemistry: sixth ed.; Dickson, T. R.; John Wiley & Sons, Inc.; 1991
6. "Physics"; 2nd ed.; Giancoli, Douglas C.; Prentice Hall, Inc.; 1985.
7. "Modern Physics"; Holt, Rinehart and Winston, Publishers; 1976
8. NIST Special Publication 330; "The International System of Units"' National Institute of Standards and Technology; 1991

Instructional Aids:

Overheads, overhead projector/screen, chalkboard/whiteboard

LESSON PLAN   INSTRUCTOR'S NOTES

I. LESSON INTRODUCTION

   A. Self Introduction

      1. Name

      2. Phone number

      3. Background

   B. Motivation

     A knowledge of the unit analysis and conversion process is a necessity for the RCT. It is useful for air and water sample activity calculations, contamination calculations, and many other applications.

   C. Overview of Lesson

      1. Units

      2. Unit systems

      3. Unit analysis and conversions including use of conversion factor tables

   D. Introduce Objectives   O.H.: Objectives

II. LESSON OUTLINE

   A. UNITS AND MEASUREMENTS

      1. Units are used to express physical quantities or measurements, i.e., length, mass, etc. All measurements are actually relative in the sense that they are comparisons with some standard unit of measurement. Two items are necessary to express these physical quantities:

        a. A number--expresses the magnitude.

        b. A unit--expresses the dimension.

      2. A number and a unit must both be present to define a measurement.

      3. Measurements are algebraic quantities and as such may be mathematically manipulated subject to algebraic rules.

      4. **Fundamental Quantities**   See Fig. 1 - "Fundamental Units"

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a. All measurements or physical quantities can be expressed in terms of three fundamental quantities. They are called fundamental quantities because they are dimensionally independent. They are:

   1) *Length* (L)

   2) *Mass* (M) (not the same as weight)

   3) *Time* (T)

5. **Derived Quantities**

a. Other quantities are derived from the fundamental quantities. Derived quantities are formed by multiplication and/or division of fundamental quantities. For example:

   1) Area is the product of *length* times *length* (width), which is $L \times L$ or L^2

   2) Volume is area times length, which is *length* times *length* times *length*, or L^3

   3) Velocity is expressed in *length* per unit *time*, or L/T

   4) Density is expressed in *mass* per unit volume, or M/L^3

B. SYSTEMS OF UNITS   Objective 1.02.01

1. The units by which physical quantities are measured are established in accordance with an agreed standard. Measurements made are thereby based on the original standard which the unit represents. The various units that are established, then, form a *system* by which all measurements can be made.

2. **English System**   See Table 1 - "English System Base Units"

a.   The system that has historically been used in the United States is the English System, sometimes called the English Engineering System (EES). Though no longer used in England, many of the units in this system have been used for centuries and were originally based on common objects or human body parts, such as the foot or yard. Though practical then, the standards for these units were variable as the standard varied from object to object or from person to person.

b.   Even though fixed standards have since been established for these antiquated units, no uniform correlation exists between units established for the same quantity. For example, in measuring relatively small lengths there are inches, feet and yards. There are twelve inches in a foot, and yet there are only three feet in a yard. This lack of uniformity makes conversion from one unit to another confusing as well as cumbersome. However, in the U.S., this system is still the primary system used in business and commerce.

3. **International System of Units (SI)**

a.   Since the exchange of scientific information is world-wide today, international committees have been set up to standardize the names and symbols for physical quantities.

b.   In 1960, the **International System of Units** (abbreviated SI from the French name Le **S**ystème **I**nternationale d'Unites) was adopted by the 11th General Conference of Weights and Measures (CGPM).

LESSON PLAN   INSTRUCTOR'S NOTES

c. The SI or modernized **metric system**, is based
    on the decimal (base 10) numbering system.
    First devised in France around the time of the
    French Revolution, the metric system has since
    been refined and expanded so as to establish a
    practical system of units of measurement suitable
    for adoption by all countries. The SI system
    consists of a set of specifically defined units and
    prefixes that serve as an internationally accepted
    system of measurement. Nearly all countries in
    the world use metric or SI units for business and
    commerce as well as for scientific applications.

4. **SI Prefixes**   Objective 1.02.02

a. The SI (or modernized) system is completely
    decimalized and uses prefixes for the base units
    of *meter* (m) and *gram* (g) as well as for derived
    units, such as the *liter* (l) which equals 1000 cm^3.

b. SI prefixes are used with units for various   See Table 2 - "SI Prefixes"
    magnitudes associated with the measurement
    being made. Units with a prefix whose value is a
    positive power of ten are called *multiples*. Units
    with a prefix whose value is a negative power of
    ten are called *submultiples*.

c. For example, as a point of reference, the meter is
    a little longer than a yard. Try using a yard stick
    to measure the size of a frame on film for a
    camera. Instead you would use inches, because
    it is a more suitable unit. With the metric
    system, in order to measure tiny lengths, such as
    film size, the prefix *milli-* can be attached to the
    meter to make a millimeter, or 1/1000 of a
    meter. A millimeter is much smaller and is ideal
    in this situation. On the other hand, we would
    use a prefix like *kilo-* for measuring distances
    traveled in a car. A *kilometer* would be more
    suited for these large distances than the meter.

d. Prior to the adoption of the SI system, two   See Table 3 - "Metric
    groups of units were commonly used for the   Subsystems"
    quantities length, mass and time: **MKS** and
    CGS.

5. **SI Units**

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a.   In the SI system there are seven fundamental physical quantities. These are length, mass, time, temperature, electric charge, luminous intensity, and molecular quantity (or amount of substance). In the SI system there is one and only one SI unit for each physical quantity.   The SI system base units are those in the metric MKS system. Table 4 lists these seven fundamental quantities and their associated SI unit. The units for these seven fundamental quantities provide the base from which the units for other physical quantities are derived.

See Table 4 - "International System (SI) Units"

b.   For most applications the RCT will only be concerned with the first four quantities as well as the quantities derived from them.

6. **Radiological Units**

a.   In the SI system, there are derived units for quantities used for radiological control. These are the becquerel, the gray and the sievert. The SI unit of activity is the becquerel, which is the activity of a radionuclide decaying at the rate of one spontaneous nuclear transition per second. The gray is the unit of absorbed dose, which is the energy per unit mass imparted to matter by ionizing radiation, with the units of one joule per kilogram. The unit for dose equivalent is the sievert, which is the absorbed dose of ionizing radiation multiplied by the dimensionless factors and other multiplying factors with the units of joule per kilogram. These quantities and their applications will be discussed in detail in Lesson 1.06.

7. **Other units**

a.   There are several other SI derived units that are not listed in table 4. It should be noted that the SI system is evolving and that there will be changes from time to time. The standards for some fundamental units have changed in recent years and may change again as technology improves our ability to measure even more accurately.

C. UNIT ANALYSIS AND CONVERSION PROCESS   Objective 1.02.03

1. **Units and the Rules of Algebra**

   a. Remember that a measurement consists of a number and a unit. When working problems with measurements, it should be noted that the units follow the same rules as the values. Some examples are provided below.

$$(cm) \times (cm) = cm^2$$

$$\frac{ft^3}{ft} = ft^2$$

$$\frac{1}{yr} = yr^{-1}$$

   b. As mentioned above, measurements are subject to algebraic laws of operation and can therefore be multiplied, divided, etc., in order to convert to a different system of units. Obviously, in order to do this, the units must be the same. For example, a square measures one foot in length and 18 inches in width. To find the area of the square in square inches we must multiply the length by the width. However, the measurements are in different units, and cannot be multiplied.

   c. We can convert feet to inches. We know that there are 12 inches in one foot. We can use this ratio to convert 1 foot to 12 inches. We can then calculate the area as 12 inches $\times$ 18 inches, which equals 216 in^2, which is a valid measurement.

2. **Steps for Unit Analysis and Conversion**

   a. Determine given units and desired units.

   b. Build (or obtain) conversion factor(s) -- see Conversion Tables at end of lesson

1) A conversion factor is a ratio of two equivalent physical quantities expressed in different units. *When expressed as a fraction, the value of all conversion factors is 1.* Because it equals 1, it does not matter which value is placed in the numerator or denominator of the fraction.

2) Examples of conversion factors are:

$$\frac{365 \; days}{1 \; year}$$

$$\frac{12 \; inches}{1 \; foot}$$

$$\frac{1 \; foot^3}{2.832E4 \; cm^3}$$

3) Building conversion factors involving the metric prefixes for the same unit can be tricky. This involves the conversion of a base unit to or from a subunit or superunit.

4) To do this, use the following steps:

Example: 1 gram to milligrams

a) Place the base unit in the numerator and the subunit/ superunit in the denominator (or vice versa).

$$\frac{g}{mg}$$

b) Place a 1 in front of the subunit/superunit.

$$\frac{g}{1 \; mg}$$

c) Place the value of the prefix on the subunit/ superunit in front of the base unit.

m (*milli-*) = 10^{-3} or 1E-3

$$\frac{1E\text{-}3\ g}{1\ mg}$$

5) Also remember that algebraic manipulation can be used when working with metric prefixes and bases. For example, 1 centimeter = 10^{-2} meters. This means that 1 meter = $1/10^{-2}$ centimeters, or 100 cm. Therefore, the two conversion factors below are equal:

$$\frac{1E\text{-}2\ m}{1\ cm} \qquad \frac{1\ m}{100\ cm}$$

c. Set up an equation by multiplying the given units by the conversion factor(s) to obtain desired units.

1) When a measurement is multiplied by a conversion factor, the units (and probably the magnitude) will change; however, the actual measurement itself does not change. For example, 1 ft and 12 inches are still the same length; only different units are used to express the measurement.

2) By using a "ladder" or "train tracks," a series of conversions can be accomplished in order to get to the desired units. By properly arranging the numerator and denominator of the conversion factors, given and intermediate units will cancel out by multiplication or division, leaving the desired units. Some examples of the unit analysis and conversion process follow.

3. Example 1:

Convert 3 years to seconds.

Step 1 - Determine given and desired units

Given units: years

Desired units: seconds.

Step 2 - Build/obtain conversion factor(s)

   We can use multiple conversion factors to
   accomplish this problem:

   1 year = 365.25 days

   1 day = 24 hours

   1 hour = 60 minutes

   1 minute = 60 seconds

Step 3 - Analyze and cancel given and intermediate
units.   Perform multiplication and division of
numbers.

$$\left(\frac{3\ years}{}\right)\left(\frac{365.25\ days}{1\ year}\right)\left(\frac{24\ hours}{1\ day}\right)\left(\frac{60\ minutes}{1\ hour}\right)\left(\frac{60\ seconds}{1\ minute}\right) = 94{,}672{,}800\ se$$

4. Example 2:

   What is the activity of a solution in $\frac{\mu Ci}{ml}$ if it has

   $2000\ \frac{dpm}{gallon}$?

   Step 1 - Determine given and desired units.

      Given units: $\frac{dpm}{gallon}$

      Desired units: $\frac{\mu Ci}{ml}$

   Step 2 - Build conversion factor(s).

      1 liter = 0.26418 gallons

      1 dpm = 4.5 E-07 uCi

      1 liter = 1000 ml

Step 3 - Analyze and cancel given and intermediate
units. Perform multiplication and division of
numbers.

$$\left(\frac{2000\ d\!\!\!/pm}{g\!\!\!/al}\right)\left(\frac{4.5E\text{-}7\ \mu Ci}{1\ d\!\!\!/pm}\right)\left(\frac{0.26418\ g\!\!\!/al}{1\ \ell}\right)\left(\frac{1\ \ell}{1,000\ ml}\right) = 2.38E\text{-}7\ \frac{\mu Ci}{ml}$$

D. TEMPERATURE MEASUREMENTS AND CONVERSIONS

Objective 1.02.04

1. Temperature measurements are made to determine the amount of heat flow in an environment. To measure temperature it is necessary to establish relative scales of comparison. Three temperature scales are in common use today. The general temperature measurements we use on a day-to-day basis in the United States are based on the **Fahrenheit** scale. In science, the **Celsius** scale and the **Kelvin** scale are used.

See Fig. 2 - "Comparison of Kelvin, Celsius and Farhrenheit scales"

2. The Fahrenheit scale, named for its developer, was devised in the early 1700's. This scale was originally based on the temperatures of human blood and salt-water, and later on the freezing and boiling points of water. Today, the Fahrenheit scale is a secondary scale defined with reference to the other two scientific scales. The symbol °F is used to represent a degree on the Fahrenheit scale.

3. About thirty years after Fahrenheit scale, Anders Celsius, a Swedish astronomer suggested that it would be simpler to use a temperature scale divided into one hundred degrees between the freezing and boiling points of water. For many years his scale was called the **centigrade** scale. In 1948 an international conference of scientists named it the Celsius in honor of its inventor. The Celsius degree, °C, was defined as 1/100 of the temperature difference between the freezing point and boiling point of water.

LESSON PLAN   **INSTRUCTOR'S NOTES**

4. In the 19th century, an English scientist, Lord
    Kelvin, established a more fundamental temperature
    scale that used the lowest possible temperature as a
    reference point for the beginning of the scale. The
    lowest possible temperature, sometimes called
    absolute zero, was established as 0 K (zero Kelvin).
    This temperature is 273.15°C below zero, or
    -273.15°C. Accordingly, the Kelvin degree, K, was
    chosen to be the same as a Celsius degree so that
    there would be a simple relationship between the two
    scales.

5. Note that the degree sign (°) is not used when stating
    a temperature on the Kelvin scale. Temperature is
    stated simply as kelvins (K). The kelvin was adopted
    by the 10th Conference of Weights and Measures in
    1954 and is the SI unit of thermodynamic
    temperature. Note that the degree Celsius (°C) is
    the SI unit for expressing Celsius temperature and
    temperature intervals. The temperature interval one
    degree Celsius equals one kelvin exactly. Thus,
    0°C = 273.15 K by definition.

6. To convert from one unit system to another, the   See Table 5 - "Equations
    following formulas are used: for Temperature
                                                              Conversons"

1) $°C = \dfrac{(°F-32)}{1.8}$

   or

   $°C = (°F-32)\left(\dfrac{5}{9}\right)$

2) $°F = 1.8(°C) + 32$

   or

   $°F = \left(\dfrac{9}{5}\right)(°C) + 32$

3) $K = °C + 273.15$

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7. Example 3:

    Convert 65° Fahrenheit to Celsius.

$$°C = \frac{(65°F - 32)}{1.8}$$
$$°C = \frac{33}{1.8}$$
$$°C = 18.3°C$$

III. SUMMARY

A. Review major topics

1. Units

2. Unit systems

3. Unit analysis and conversions including use of conversion factor tables

B. Review learning objectives

IV. EVALUATION

Evaluation shall consist of a written examination comprised of multiple choice questions. 80% shall be the minimum passing criteria for the examination.